Rate-Distortion control for H.264/AVC in video compression systems with memory restriction

Ann Ukhanova
St. Petersburg University of Aerospace Instrumentation
Rate Control

Rate control guarantees that the resulting image size is not higher than the given threshold value.

Rate control mechanism is required to map varying encoder output bit rate onto the constant bit rate channel.
Rate Control algorithm in H.264

**Main idea:** choose $Q_t$ so that $b(t) \approx B'$

**Problem:** $r(Q_t)$ can’t be computed in advance before encoding and can be only predicted

- **Buffer filling up**
  - the *quantization step size* in the encoder is increased which increases the compression factor and reduces the output bit rate
- **Buffer starts to empty**
  - the *quantization step size* is reduced which reduces compression and increases the output bit rate
A leaky bucket is a direct metaphor for the encoder’s buffer.

Hypothetical reference decoder of a given buffer size should decode the video bit stream without suffering from buffer overflow or underflow.
Transmission system with preliminary compression

Depending on the channel rate decoder chooses the initial start-up delay according to the information about pairs \((R_{\text{min}}, B_{\text{min}})\) received from the encoder.

\[
R_1 < R_2 \implies B_1 > B_2
\]
Real-time compression and transmission system

\[ b(t) = \max \{0, b(t-1) - r\} + r(Q_t), \]

where \( b(t) \) – number of bits in the buffer at time moment \( t \),
\( r \) – channel rate
Problem statement

• System of video compression and transmission (based on H.264/AVC)
  – small memory consumption at transmitter/receiver (256x16)
  – single video frame 1024x768, 25 Fps

Resume: No motion compensation, only Intra frames

Goal: provide the acceptable level of quality for video sequence for a given channel throughput
Delay requirements

\[ \Delta T = \Delta T_e + \Delta T_{eb} + \Delta T_c + \Delta T_{db} + \Delta T_d \]

\[ \Delta T_e = \Delta T_d = \frac{1}{Fps \cdot N} \]

\[ \Delta T_{eb} + \Delta T_c + \Delta T_{db} = L \]

\[ \begin{align*}
B^e_{\text{max}} &= B^d_{\text{max}} = L \cdot r \\
b^e(t) &\leq B^e_{\text{max}}
\end{align*} \]
Delay values for H.264

![Graph showing buffer fullness over tile # for different L values and CR settings.]

- L = 7 frames
- L = 2 frames
- L = 0.15 frame

Legend:
- opera, CR=10
- opera, CR=20
- desktop, CR=10
PSNR fluctuations for H.264

![Graph showing PSNR fluctuations for H.264 with curves for opera and desktop, CR=10.]

- 25 dB
- 55 dB
- original
Proposed RD-control

Optimization task (for all tiles):

\[
\begin{align*}
\text{minimize } \max_t d(Q_t) \\
\text{subject to } b(t) \leq B_0
\end{align*}
\]

where \( b(t) = \max \{0, b(t-1) - r\} + r(Q_t) \),
Proposed algorithm

- Transmit current tile with distortion $\hat{d}(t)$
- Transmit current tile with distortion $d_{\text{empty}}$

\[
b(t) = 0 \quad / \quad \hat{d}(t+1) = \hat{d}(t) + \Delta d
\]

Graph showing buffer state over tile number with accumulation and emptying thresholds.
Original vs. proposed algorithms

JPEG2000

H.264/AVC

Frame Num

tile #

PSNR(Y) dB

Expectations for the proposed algorithm

Original algorithm

JPEG2000 with tiling  Proposed algorithm
Summary

• H.264 original Rate Control algorithm is good for transmission scheme with preliminary compression

• For real-time compression and transmission another approaches should be used
Other papers on this theme